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Results from a Cooperative Federal, State, and Trade Association Waste Minimization Research Program

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16. ABSTRACT

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ABSTRACT

The U.S. EPA Office of Research and Development supported a waste minimization research program in 1986-1988 for small and medium sized generators to develop and promote the use of innovative technologies and management practices to reduce the generation of hazardous wastes. This program was established in response to the needs of small quantity hazardous waste generators in the areas of waste management, regulatory compliance, and waste reduction. Waste reduction is seen as one key way to help small businesses improve waste management by reducing liability, product costs, disposal costs, and environmental, health, and safety concerns. At the time, the program consisted of two efforts with the State of Minnesota and the Governmental Refuse Collection and Disposal Association (GRCDA). Results from these two cooperative research efforts are being used to assist small and medium sized businesses work toward waste reduction, improve waste management, and achieve regulatory compliance. Results from these two efforts are presented in this paper.

INTRODUCTION

In the spring of 1986, EPA's Office of Research and Development established a two-year cooperative agreement with the Minnesota Waste Management Board through the Minnesota Technical Assistance Program (MnTAP), and a second two-year cooperative agreement with the Governmental Refuse Collection and Disposal Association (GRCDA). The purpose of these cooperative efforts was to design and implement a research program within the State of Minnesota that would provide small and medium-sized hazardous waste generators with new methods or technologies for waste minimization, and to transfer the research results to the industry and states through an active waste management trade association. EPA believes that waste management, or pollution prevention, is the best solution to the unique waste management problems of small and

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medium-sized generators. Waste minimization is more efficient and economically sound and makes more business sense than end-of-pipe treatment and disposal. Results from this program to date have provided practical, economical and sound waste minimization solutions to assist waste generators. This non-regulatory cooperative effort with federal, state and industry has proven to be a successful approach for encouraging industries, especially small businesses and local governments, to use innovative technologies and management practices that reduce waste generation, prevent pollution, and provide economic benefits.

THE CONCEPT OF POLLUTION PREVENTION FOR SMALL AND MEDIUM INDUSTRY

Waste minimization, or pollution prevention, is a feasible approach to hazardous waste management for all waste generators. By reducing the volume of waste generated at the source, and thus reducing reliance on land disposal, a number of benefits can be incurred, including fewer environmental, health and safety concerns, improved regulatory compliance, reduced liability, and significant savings from avoided disposal and raw material costs. The obvious consequences of land disposal as a waste management method have been poor management of hazardous waste, groundwater contamination, and other hazards to human health and the environment. Waste minimization, as currently defined by the EPA in its report to Congress (1) includes any "source reduction" or "recycling" activity undertaken by a hazardous waste generator that results in: 1) the reduction of the amounts of hazardous waste that will require treatment or disposal, and/or 2) the reduction of the toxicity of the hazardous waste, so long as such reductions are consistent with the goal of eliminating or reducing present and future threats to human health and the environment. The Office of Technology Assessment (OTA) submitted its report to Congress (2) in October 1986 defining waste reduction as in-plant practices that reduce, avoid, or eliminate the generation of hazardous waste so as to reduce risks to health and the environment. EPA has also chosen to emphasize "in-plant reduction" as opposed to "off-site recycling" in its research program. In addition, the EPA waste minimization research program has application to the air and water pollution areas, resulting in a multi-media approach. Finally, to illustrate its commitment to waste minimization, EPA has established a new Office of Pollution Prevention within the Office of Policy Planning and Evaluation (OPPE). The goal of this new office is to foster pollution prevention across all media both inside and outside the Agency.

TECHNOLOGY TRANSFER THROUGH TRADE ASSOCIATIONS

To meet the technology transfer and information needs of hazardous waste generators, the U.S. EPA established the Governmental Refuse Collection and Disposal Association (GRCDA) Information and Technical Assistance Clearinghouse in March 1986.

The GRCDA is an association of waste management professionals dedicated to promoting environmental compliance by providing technical information and education to those who wish to better the waste management industry. One of the objectives of the EPA/GRCDA cooperative agreement was to provide for a national technical information transfer of waste minimization research such as the research conducted under the EPA/Minnesota cooperative agreement. It was determined that trade associations are generally responsive to the needs of their members and will work with other trade associations to meet these needs.

Under the Clearinghouse, a number of services were established to foster an information exchange and transfer of waste minimization/waste management technology information. The services provided to achieve these goals include:

- o A Toll Free Hotline

  The Clearinghouse Hotline (1-800-458-5886) puts the caller in direct contact with GRCDA staff who can provide immediate technical assistance. This includes information on proper waste management practices, waste minimization technologies and current regulatory program developments.

- o Technical Referral Service

  The Clearinghouse, as a national focal point for waste management information, developed a network of state, regional and technology specific programs throughout the United States. This made it possible for GRCDA staff to link together information requests with the best sources.

- o Clearinghouse Library

  The Clearinghouse Library is a compilation of publications produced by the public and private sector on waste management issues. Most often these resource materials are photocopied by the staff and sent out upon request or to supplement an assistance effort. For copywrite materials, ordering information through the publisher is provided. Reports from other aspects of the U.S. EPA waste minimization research program are also contained here for distribution.

During the 36 months the Clearinghouse has operated, technical assistance has been directly provided to approximately 500 businesses and others involved in waste management issues. GRCDA staff have also made presentations at conferences, contributed to publications and periodicals, and worked with related trade associations and assistance programs.

The funding for the Clearinghouse ended on September 30, 1988. GRCDA continues to operate the Clearinghouse by charging for photocopying, shipping, and handling of publications. The hotline number (1-800-458-5886) is still available for technical assistance. The GRCDA staff now publish "HAZ-X-CHANGE", a newsletter to strengthen the network of programs with consistent contact to the generator. "HAZ X CHANGE" was first sent out free of charge in the late summer of 1988 to 400 regulatory and non-regulatory federal, state and local agencies, technical assistance programs, trade associations, research facilities and waste exchanges. A subscription rate of $25.00 will now be associated with the quarterly newsletter.

STATE RESEARCH PROGRAM RESULTS

The nine research projects supported by the cooperative agreement (50% non-EPA matching funds) focused on the special needs of Minnesota generators, but have application to hazardous waste generators across the country.

This work was conducted through the Minnesota Waste Management Board and Minnesota Technical Assistance Program (MnTAP). The

objective of the MnTAP program is to provide technical assistance to small quantity generators in Minnesota to reduce hazardous waste. In response to generator needs in Minnesota, MnTAP offers several services to foster and implement waste reduction in industry including telephone consultation, on-site consultation, a student intern program, and an information clearinghouse for Minnesota businesses. Results from each of the nine projects are presented according to the following categories: 1) Laboratory Wastes; 2) Metal Finishing Wastes; 3) Radiator Repair Wastes; 4) Oily Wastes; 5) Pesticide Wastes; and 6) Solvent Wastes.

Laboratory Wastes

Chromic Acid Waste Treatment/Recycling/Disposal

Chromium is used in a variety of forms in laboratories, most commonly as chromic acid cleaning solution, a mixture of sulfuric acid and potassium dichromate, that makes a very strong cleaning agent for removal of organic material from laboratory glassware. Disposal of spent chromic acid cleaning solutions has posed a significant problem for academic, clinical, industrial, and commercial laboratories. The most common disposal practice for these solutions has been landfilling by the lab pack method. However, with the July 1987 landfill ban a limited number of commercial treatment options exist. The overall objective of this study, conducted at the University of Minnesota, Department of Environmental and Occupational Health, was to examine the costs and practicality of alternative methods for handling waste chromic acid cleaning solution, including 1) a laboratory chemical reduction method; 2) in-lab chromium recovery using disposable ion exchange columns; 3) off-site treatment/recovery of solutions; and 4) substitutes for chromic acid cleaners. Results from evaluation of these options follow and are summarized in Table 1.

Laboratory chemical reduction of chromic acid cleaning solutions successfully precipitated chromium from solution, leaving an effluent of sewerable quality (< 2 ppm chromium). Chromic acid cleaning solutions are in the hexavalent state upon exposure to soiled glassware, at which time most of the chromium is reduced to the trivalent state. However, not all of the chromium is reduced, and spent solutions are made up of both trivalent and hexavalent forms. Further reduction by adding sodium thiosulfate is necessary to get all the chromium into the less toxic trivalent state before it is precipitated out of the solution. The residue from this process is a well-mixed solid made up of trivalent chromium oxide, filtration media, and some sodium sulfate.

Use of ion exchange columns on chromic acid cleaners produced a sewerable effluent (< 2 ppm chromium). The procedure for ion exchange involved using a disposable column containing both cation and anion resins to remove both trivalent and hexavalent chromium, respectively. While ion exchange requires minimal effort and hazard, this treatment method is very expensive due to the rapidity with which the ion exchange column becomes exhausted.

Telephone interviews showed that commercial metal recyclers have shown little interest in small volumes of chromium for recycling due to currently low market value. The cost of transportation and handling of small quantities of chromic acid wastes exceeds the revenue potential of the recovered chromium. In addition, many firms prefer to receive chromium in the hexavalent state.

Table 1 indicates that for small volume laboratory generation of chromic acid cleaning solutions the in-laboratory reduction method has the greatest application for small quantity generators

due to low cost, ease of conducting the treatment, and the fact that it can be carried out safely in the laboratory by using proper techniques. Of course, where possible, substitution of other cleaners for chromic acid should be made.

A number of laboratories were found to use substitutes for chromic acid cleaners. The types of substitutes included detergents, potassium hydroxide, sonic baths or a combination of these. The advantage of using substitutes is that they are less hazardous to work with and in many cases sewerable after use. Although the cost of substitutes is comparable to chromic acid solutions and they may take longer to clean, the savings on disposal costs can be substantial.

TABLE 1

Advantages and Disadvantages of Treatment and Disposal Methods and Alternatives to Chromic-Acid Solutions

Chromium reduction	Moderate Cost Effective Chromium removal Stable Product Volume Reduction	Potential hazard to lab personnel
Ion Exchange	Effective Quick, simple	Very high cost Requires disposal of column
Substitutes	Low cost of disposal Sewerable Low personnel hazard potential	May not be as effective
Commercial collection	Low to moderate cost Useful to raw waste or residue	Extra storage space needed

Microscaling Instructional Laboratory Experiments

A large amount of information has been compiled concerning the effects of certain hazardous and toxic chemicals upon exposure to individuals in the laboratory and other work environments. Of particular concern is exposure of students to laboratory chemicals while conducting experiments in academia or industry. As a result of this concern, the St. Paul Technical Institute decided to undertake a concerted effort to reduce and/or eliminate the use of certain hazardous chemicals in its Chemical Technology Program. A one year project was undertaken in which two years worth of chemistry laboratory experiments (six quarters) were written or modified, to eliminate or reduce the hazardous chemicals used through either microscaling or substitution techniques, thus reducing hazardous waste generation.

A total of 106 chemistry laboratory experiments were newly written or modified, tested in the instructional lab as part of the Chemical Technology Program, modified based on student/instructor review, and compiled into two laboratory manuals. The experiments are a combination of organic and inorganic tests taught to students to prepare them for industrial laboratory testing. The Chemical

Technology Program is a two-year program in which the first and second year are taught concurrently by separate instructors. Thus, it was easy to complete the writing and testing of each experiment in one year. Experiments were rewritten from other sources or written as original experiments, taking care to microscale to minimal amounts of chemical used or to substitute less hazardous or non-hazardous waste. Each experiment was used and tested by at least one student during the school year as part of the curriculum and evaluated for clarity and performance. Based on the evaluation, the experiments have been modified and finalized in two laboratory manuals.

Compared to previous years of operating the Chemical Technology Program, no solvent waste that could not be reclaimed and reused was generated during this past year of running the project using microscaled experiments. Only a very small amount of solid hazardous waste was generated and will have to eventually be shipped for incineration.

Results from this project should enable chemistry instructional laboratories waste to reduce hazardous material usage and hazardous waste generation by incorporating selected experiments into their upper-level high school or lower- level college chemistry curriculum. An additional benefit includes increased health and safety to students and workers in laboratory and industrial settings.

Metal Finishing Wastes

Biological Degradation of Cyanide by Nitrogen-Fixing Cyanobacteria

Metal-cyanide complexes are a common contaminant in electroplating wastestreams. Conventional treatment of cyanide-containing wastewaters, using alkaline chlorination, may leave some residual cyanide and chemical costs are high. A method has been examined in this study to use nitrogen-fixing cyanobacteria (blue-green algae) in the biological treatment of small concentrations of free cyanides (HCN and CN^-) as a cost-effective alternative to conventional cyanide treatment processes. A potential application of a cyanobacteria-based process would be in the secondary treatment of the cyanide that escapes alkaline chlorination. Because the extent of cyanide oxidation is an equilibrium-driven reaction, use of a microbial process to detoxify the last fraction of cyanide should result in lower alkaline chlorination costs.

The specific objectives of this study conducted by the University of Minnesota, Civil and Mineral Engineering Department, were: 1) to determine the rates at which nitrogen-fixing blue-green algae (Anabaena) cultures decrease total cyanide concentrations; and 2) to determine the rate at which HCN is reduced to methane by nitrogenase activity. Rates of total cyanide biodegeneration were determined in a 1.3-liter reactor under batch conditions with initial cyanide concentrations of 3.0 mg/l (3 ppm). The extent of cyanide volatilization was measured for each batch test, so that the reported rate constants represented biodegradation and not the sum of biodegradation and volatilization. The methane production experiments were conducted in small 0.037-liter, gas-tight vials under batch conditions with initial cyanide concentrations of 30 to 400 ug/l (30-400 ppb).

The rate of cyanide biodegradation was found to follow mixed second order kinetics to describe the biologically-mediated decrease in cyanide for reactors containing initial cyanide concentrations of 3 ppm. For Anabaena cultures not previously exposed to cyanide, the rate constants were a function of pH.

Faster rates of cyanide biodegradation were observed at higher pH values. Anabaena cultures acclimated to the presence of cyanide had rate constants that were at least 10 times faster than rate constants for unacclimated cultures.

Mixed second-order rate constants were also obtained for the ability of nitrogenase, the enzyme normally responsible for nitrogen-fixation, to reduce hydrogen cyanide to methane and ammonia. In batch reactors with initial cyanide concentrations of 30 ppb, the rate constants for methane production were at least 10 times faster than expected based on literature values for nitrogen fixation, suggesting that nitrogenase will preferentially use hydrogen cyanide as a substrate compared to molecular nitrogen. Also the rate constants for methane production were of the same order of magnitude as the rate constants for total cyanide removal, indicating that nitrogenase is an important mechanism for the degradation of trace concentrations of cyanide.

The magnitude of the cyanide biodegradation rate constants suggests that the utilization of nitrogen-fixing cyanobacteria in the treatment of cyanide wastes can be a feasible process in some applications, such as secondary or tertiary treatment at larger facilities. Several potential advantages exist with the use of this concept: 1) cyanobacteria are photosynthetic, and do not require aeration or the presence of substrates to maintain biomass, resulting in lower operating costs; 2) nitrogen-fixing cyanobacteria have the ability to survive in low to moderate concentrations of hydrogen cyanide, due to the presence of cyanide-resistant respiration and cyanide detoxification pathways; 3) nitrogen-fixing cyanobacteria can destroy hydrogen cyanide with the enzyme nitrogenase, converting it to methane and ammonia.

Recovery of Metals From Metal Finishing Waste Streams Using Aluminum Displacement

Copper and lead in low concentrations are common contaminants in waste streams generated by the printed circuit industry. These heavy metals, along with several others, render the rinsewaters produced by fabrication processes, such as cleaning, etching, and plating, toxic when present above certain concentrations (1.0-10.0 mg/l). Standard practice for pretreatment of these wastes to reduce heavy metal concentrations produces a sludge which must be handled and disposed as a hazardous waste. However, the proposed ban on landfilling untreated sludges from metal finishing operations will increase these disposal costs dramatically. In addition, valuable resources are wasted by not recovering metals for reuse.

One method for recovering metals from acidic waste streams, first reported in the mid-1960s, uses aluminum to displace metal ions from solution. Due to the position of aluminum in the electromotive series, metal ions with lower oxidation potentials such as copper and lead are reduced to their metallic state if brought into contact with aluminum metal under certain conditions. While recovery systems taking advantage of this reaction have been in use for some time, questions remained about their applicability to the low-volume, variable waste streams typically generated by small quantity generators. This study, conducted by Circuit Chemistry Corp., Maple Plain, MN, examined variables which might affect the implementation of this process, including flow rates, contact times, solution pH and waste stream composition.

The reactor designed and built to examine these variations is shown in Figure 1. Air agitation is used to produce mechanical motion in the reactor to remove metal particles from the surface of the aluminum as displacement occurs. These metal particles are

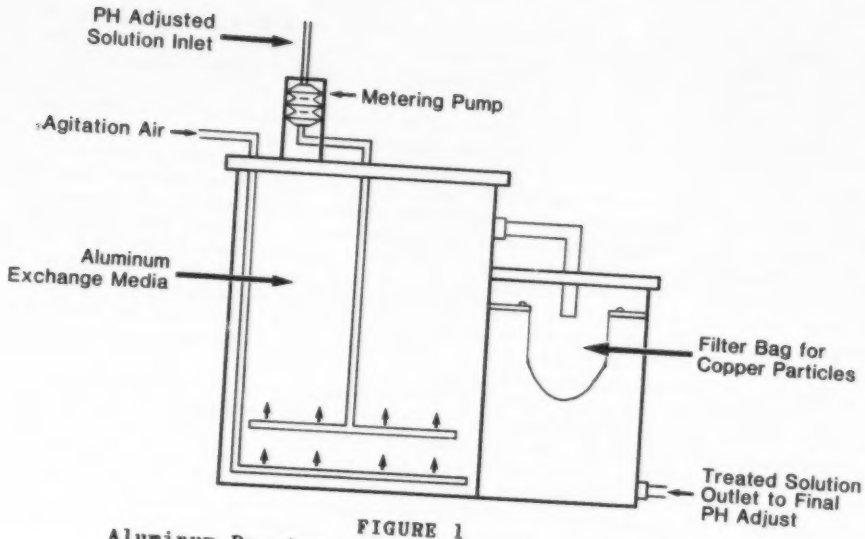

FIGURE 1
Aluminum Reactor Test Equipment Flow Diagram

collected both by pumping the solution from the bottom of the reaction chamber through a filter cartridge and by passing overflow solution through a filter bag. The same reactor was used to test metal removal efficiencies on a "flow-through" (one pass through the aluminum) and a "recirculating" (several passes through the aluminum) basis. Operating this process using recirculation is seen to have potential for use with low-volume waste streams which could be accumulated for treatment.

Initial testing was performed in a fabricated waste stream of copper sulfate in solution at a metal concentration of 200 mg/l. Metal removal efficiency was evaluated at various flow rates and solution pH, finally arriving at an optimal flow of 0.15 gpm and a pH of 2.5. These were then used during evaluation of metal removal efficiency from other solutions common to printed circuit fabrication, summarized in Table 2. Results of this testing are summarized in Table 3.

TABLE 2

Solutions Common to Printed Circuit Fabrication

Copper sulfate	- Most common electroplating solution used for printed circuit manufacturing
Copper ammonia chloride	- Alkaline etchant used to remove copper from bare or copper-plated printed circuit boards
Copper/EDTA	- Very common electroless plating solution complex
Hydrogen peroxide/sulfuric acid	- Etchant used to clean copper surfaces
Copper nitrate	- Solution resulting from use of nitric acid to strip racks used to hold work during processing
Tin/lead fluoborate	- Common electroplating solution
Solder brightener	- Removes small amounts of tin and lead from printed circuit boards as part of post-processing cleaning.
Nickel sulfate	- Electroplating solution

TABLE 3

Results from Metal Removal Efficiency Testing

Waste Stream	Metal	Percent Removed
1. Copper Sulfate	Copper	96
2. Copper Ammonia Chloride	Copper	90
3. Copper EDTA	Copper	51
4. Peroxide Sulfuric Etchant	Copper	89
5. Copper Nitrate	Copper	0
6. Lead Fluoborate	Lead	90
7. Tin Chloride	Tin	85
8. Nickel Sulfate	Nickel	0

Copper complexed with EDTA was not removed adequately using the flow-through system, although removal might improve using recirculation. Copper nitrate showed no removal activity, possibly because the nitric acid component of this solution interferes with the reaction, reversing it as quickly as it proceeds. Also, nickel may not be removed effectively due to its position in the electromotive series relative to aluminum. Recirculation of copper sulfate and tin/lead fluoborate solutions showed reductions of metal concentrations from 200 mg/l to 1.5 mg/l and 0.65 mg/l, respectively, in 24 hours.

The results of this study indicate that displacement of metal ions from solution using aluminum holds promise as a metal recovery technology in certain applications. The low equipment cost and simplicity of operation make this an attractive option for many smaller metal finishing operations. Not only can waste stream concentrations of regulated metals be reduced to compliance levels, but these metals are recovered in a form amenable to management as a resource rather than a waste.

Radiator Repair Wastes

Metal Removal/Recovery from Radiator Repair Shop Cleaning Solutions

Radiator repair shops commonly use hot caustic solutions to clean radiator sections prior to repair and resoldering (see Figure 2). These "boil-out" solutions become contaminated with dirt, rust and paint, as well as metals at concentrations as high as 18,000 mg/l for lead, 500 mg/l for copper, and 1000 mg/l for zinc. Current management practice for these waste solutions is often bulk discharge to a sewer or shipment for treatment and disposal as a strongly caustic hazardous waste. Many radiator repair shops are small (2-10 employees) and cannot afford the costs of proper disposal ($175-225 per 55-gallon drum; $1000-2000 per year). However, since these wastes are consistently high in lead content, the possibility of recovery rather than disposal is suggested.

A secondary lead smelter could not accept these wastes "as-is", both because of high water content and copper contamination. This study, conducted by the Natural Resources Research Institute, University of Minnesota, Duluth, MN, studied the procedures needed to separate the liquid waste into copper and lead-rich fractions, which could later be dewatered for metal recovery. It was hoped

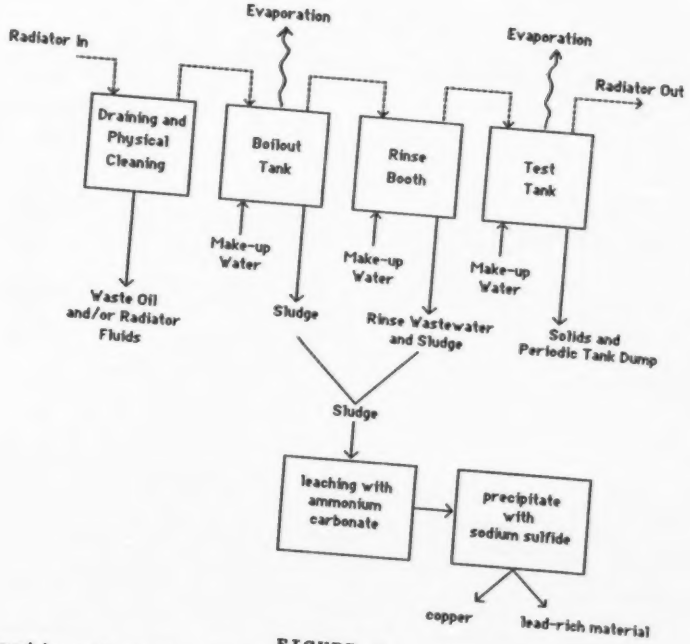

FIGURE 2
Schematic of Radiator Repair Process and Waste Treatment

that these procedures would be simple enough for a repair shop operator to perform on-site, thus eliminating the need to ship any waste for disposal.

The first operation explored was settling of the solids from the waste boil-out solutions. Cooling these solutions was found to allow dissolved metals to settle along with other solids, allowing the reuse of up to 80% of the solution. This was true regardless of whether the solution was drawn from a traditional cleaning line or an ultrasonic cleaning tank, a technology just beginning to find application in this field.

Since the settled solids contain all mixed metals, rendering the material unsuitable for smelting, methods of selective leaching were studied next. Ammonium persulfate and ammonium carbonate were both tested for their efficiency of leaching copper from the settled solids, the purpose being to put copper into solution in its ionic form, which could then be precipitated. Copper extraction of 80% was realized using ammonium carbonate; leaching using ammonium persulfate was found to be less efficient by a factor of ten.

Precipitation of metals from the leachate using sodium sulfide was then evaluated and found to reduce metal concentrations by a factor of 800:1. The precipitate proved difficult to filter, but settled readily. The combination of the leaching and precipitation steps yields a copper sulfide material and a lead-rich sludge, both with possibilities for metal recovery if dewatered.

The results of this study show that radiator boil-out tank sludge can be effectively prepared on-site for possible subsequent metal recovery. Only basic equipment (mixer, tanks) and limited labor would be necessary. While the procedures may be too complex for the smallest radiator repair shops, larger shops and those using ultrasonic systems could use these processes effectively.

Oily Wastes

Removal of Oil from Oil-Water Mixtures Using Selective Oil Filtration

Oil-containing wastewaters are generated at an estimated rate of more than one billion gallons per year in the United States. Generators of these wastestreams are extremely varied and may include petroleum refineries, metal fabrication plants, chemical processing plants, machine shops, and vehicle maintenance shops. Many different types of oils may be present in oily wastewater such as diesel fuel, cutting and grinding oils, lubricating oils, water soluble coolants, natural animal or vegetable fats or any other organic immiscible in water. The removal of these oily wastes from wastewater is of importance in preventing pollution and meeting environmental compliance standards. Oily waste removal may also be beneficial for water and oil recovery and reuse.

Several different methods are currently available for separating oil from oily wastewaters, but these are generally limited in the forms of oil that they can remove. Oily wastewaters containing chemically emulsified oil are particularly difficult to separate, and the options available for treating them are few in number.

In this study conducted by the University of Minnesota, Civil and Mineral Engineering Department, a novel membrane separation process, termed selective oil filtration (SOF) was studied as an alternative separation technique for removing emulsified oil from oil-water mixtures. SOF is similar to ultrafiltration in that microporous membranes are used. It is unlike ultrafiltration, however, in that oil rather than water is selectively removed by applying a pressure across the membrane (Figure 3).

The purpose of this research was to derive some understanding of how and why the SOF process works and to determine some of its limitations. More specifically the objectives of this research were as follows: (1) demonstrate that oil could be removed from oil-water mixtures using selective oil filtration; (2) determine the effects of various operating parameters such as pressure, feed flowrate, oil viscosity and oil concentration on process performance; (3) determine the effect of emulsion stability and the presence of emulsifying agents on the ability of the membrane to

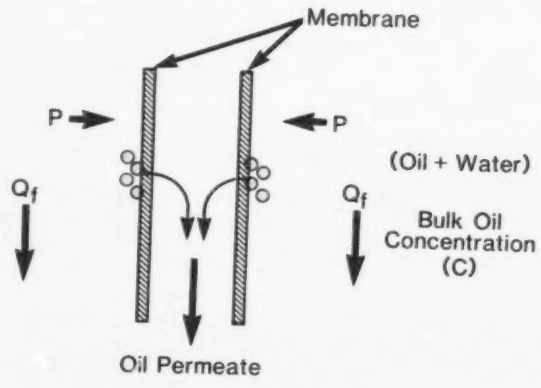

FIGURE 3
The Selective Oil Filtration Process

selectively remove oil; and (4) determine the mechanism of oil transport from the bulk solution to the permeate stream.

In this laboratory study, microporous hollow-fiber membranes were used to separate oil from oil-water mixtures using SOF. This research was carried out in two stages. Stage one concerned itself with qualitatively assessing the SOF process. Several experiments were conducted in which a naphthenic base engine oil was removed from different oil-water mixtures and the SOF process was evaluated both in the presence and absence of emulsifying agents. Two types of membranes were tested and compared in these experiments. From this work some inferences about the SOF process were made and narrower research goals were defined. The aim of stage two of this project was to achieve these research goals. During stage two the performance of the SOF process was assessed under more carefully defined conditions in which dodecane was employed as a model oil. This was done by studying the effects of various operating parameters. Dodecane was removed from dodecane-water mixtures to which sodium dodecyl sulfate was added as an emulsifying agent. An assessment of emulsion stability as a function of emulsifier concentration was also made and correlated to the observed results.

Key results from this study are given below:

1. Selective oil filtration can be used to recover a water-free oil product from oil-water mixtures in both the presence and absence of emulsifying agents.

2. Low viscosity oils, such as dodecane, are more efficiently removed than high viscosity oils such as naphthenic oil. This difference in removal efficiency is due to differences in the controlling mechanism of oil transport.

3. In this study, the transport of high viscosity oils was membrane limited whereas the transport of low viscosity oils was limited by transport and attachment to the membrane and droplet collapse.

4. The removal of low viscosity oils is strongly affected by system hydrodynamics. Oil removal rates increase with increasing feed flowrate as the opportunity for contact between the dispersed droplets and the fibers is improved.

5. The rate of oil removal is affected by the feed oil concentration. As the oil concentration increases, the rate of oil removal also increases. This study showed that this increase is not linear over a broad oil concentration range and that oil removal is limited at low oil concentrations (<1%).

6. Both anionic and nonionic surfactants or emulsifying agents have an adverse effect on oil removal. The rate of oil removal and permeate flux decreases markedly with the addition of these types of emulsifying agents.

7. SOF is not suitable for the removal of oil-wet solids, however, and prior to filtration, the suspended solids must be removed to prevent membrane fouling.

The selective oil filtration process has potential as an alternative oil-water separation technique. This process is better

suited than ultrafiltration to the treatment of oily wastewaters with a high oil concentration or for the treatment of water-in-oil emulsions. It cannot replace ultrafiltration, however, for the removal of oil from dilute oily wastewaters.

Reduction of Machine Tool Coolant Waste by Optimizing Coolant Life

Machine shops use coolants, frequently oils emulsified in water, to improve the life and function of machine tools such as drills, lathes and broaches. Coolants are allowed to flow in a continuous stream over the tool and the material being machined, carrying away excess heat generated by friction. The coolant is collected and recirculated and, over time, becomes contaminated with metal chips and "way oil" (lubricant). These contaminants create favorable conditions for the growth of anaerobic bacteria, which produce hydrogen sulfide gas, shorten coolant life, and eventually force disposal of the coolant as waste. The exact waste management scheme for this waste coolant is determined by the type of coolant, contaminants (metals, organic solvents, biocides, nitrates), and availability of treatment. Standard practice is often to drain waste coolant to the sanitary sewer after surface skimming of accumulated oils.

While coolant maintenance schemes have long been proposed by coolant suppliers as a means to extend coolant life, they have usually been ignored in favor of the simpler "use-and-dump" routine. However, as regulatory pressures and prices ($20-200 per 55-gallon drum for treatment) have increased, machine shops have begun to practice coolant maintenance with an excellent potential to extend coolant life and thereby reduce the volume of coolant waste generated. This study, conducted by Washington Scientific Industries, Inc., (WSI), Long Lake, MN, examined factors and techniques which contribute to coolant life extension.

WSI is a machine shop which uses a wide variety of tools to make parts from materials such as steel, aluminum, and copper. The machines used at WSI are medium-sized and are similar to those used in many machine shops. Machine tools chosen for monitoring during the study are one to four years old, used for jobs with long (2-4 week) production runs. Operators, materials, and processes were held constant during monitoring as much as possible. After sampling to establish baselines for parameters such as water quality, coolant quality, and health effects, the study focused on the effects on coolant life of coolant change practice, coolant maintenance, and coolant type.

Using standard industrial engineering techniques, the following procedure was established as the method of removing and replacing contaminated coolant which may extend coolant life.

1) Skim all way oil from coolant surface
2) Pump coolant from sump
3) Vacuum chips from sump
4) Remove sump access covers
5) Steam clean and vacuum sump (repeat until clear)
6) Replace sump access covers and coolant

What distinguishes this method from standard industrial practice is the complete removal of the coolant and the thorough cleaning of the sump itself, both of which are believed to remove bacterial contamination, thereby slowing degradation of the coolant.

The coolant maintenance practice which showed the most promise was skimming accumulated way oils from the surface of the coolant, thus increasing aerobic activity. Both belt- and disc- type skimmers were evaluated and found to be effective in reducing oil

and grease concentrations. As part of this evaluation, it was also discovered that many standard machine tool coolant sumps do not allow access for installation of a skimmer, which means that a capital expenditure for sump modification is often required. This may be a partial explanation of why this simple, inexpensive (less than $100) technique is not more widely used.

A specific water-soluble coolant (Blasocut 2000 Universal) was evaluated on its performance when recycled over long periods of time. It is thought that using one coolant in as many applications as possible will simplify the entire waste management scheme and allow the most efficient coolant maintenance. Blasocut 2000, even after being recycled for seven months, met or exceeded metal removal rates (a standard measure of coolant performance) for aluminum, steel, copper and stainless steel. The use of recycled coolant also does not appear to have any adverse health effects on operators, a problem which has occurred with some coolants in the form of dermatitis.

The results of this study indicate that it is possible to extend the life of machine tool coolant significantly and thereby reduce the volume of waste coolant generated. The changes documented, taken together, resulted in an extension of coolant life from an original life of 1-2 weeks to 11 months.

Pesticide Wastes

Pesticide Rinsate Recycle Facilities

Approximately 215 commercial aerial pesticide applicators and 1600 commercial ground applicators operate in the state of Minnesota. In addition, several thousand private individuals apply pesticides to their own land. During the application season, several hundred gallons of waste pesticide can be generated by an applicator each day, although volumes and types of wastes vary with the pesticide product applied and the equipment used by the applicator. These waste streams may include:

- unusable commercial chemical product
- "carried-back" unused field strength formulation
- tank and spray apparatus rinsate
- exterior wash solutions
- pesticide containers

Management of these waste pesticides ranges from proper reuse of all pesticide materials and triple rinsing pesticide containers, to improperly discharging pesticide rinsates to ditches and drainfields and burial of unrinsed containers.

The purpose of this project conducted by the Minnesota Agricultural Aircraft Association was to develop a set of generic engineering designs and specifications for recycling pesticide rinsates, with an attached operations guide for regulatory compliance.

A complete review of existing information was conducted including technical literature, existing rinsate recycle facility designs, and regulatory requirements. Ground and aerial applicators were interviewed by phone and in person to determine general operating practices and discuss practical management of waste pesticides. Regulator interviews were also conducted to ensure that system design would meet regulatory requirements.

The generic engineering plan developed for pesticide rinsate recycle incorporates recommendations for facility size, construction materials, rinsate storage volumes, reuse scheduling, and operation/maintenance procedures. With appropriate

site-specific modifications (i.e. soil considerations) the generic design is considered to be adaptable to many facility locations. Finally, aircraft and spray rig modification ideas and generic plans were also developed. This rinsate recycle facility design and compliance guide will help ensure pesticide rinsates and other wastes will be managed in an environmentally acceptable manner.

Solvent Wastes

Removal of Solvents from Wastewater by Ultraviolet Photooxidation

Developing effective, low cost technologies for removal of low level concentrations of organic solutions from wastewaters could be of great benefit in cases where pretreatment of a waste stream is necessary prior to discharge. This research work, conducted at the University of Minnesota, Department of Civil and Mineral Engineering, was aimed at evaluating the use of ultraviolet (UV) photooxidation to remove/destroy organic chemicals from wastewaters prior to sewer discharge. UV photolysis has the advantage of being an effective, low cost treatment process that can be used by small scale, low volume industrial generators of wastewater and solvent waste. The concept of using photochemical oxidation to remove organic solvents and other pollutants from wastewaters has been documented in the literature. Rates of destruction have been found to be a function of UV radiation intensity, wavelength, temperature, concentration of the organic compounds, and the presence of catalysts and chemical photosensitizers (important to accelerating oxidation of organic compounds).

UV radiation to decompose chloroorganic solutes in water results in complete removal of the organic compound, and conversion to carbon dioxide and water with release of chloride ions. A total of five organic solvents were chosen to evaluate optimal operating conditions for UV photolysis in a bench-scale photolysis unit in the laboratory. The solvents included benzoic acid, phenol, cyclohexanol, methylene chloride and 1,1,2,2-tetrachloroethane. Experiments were run with addition of potassium persulfate as an agent to enhance oxidation.

Rates of reaction for these samples was first or quasi-first order, consistent with documented literature. These results were obtained for tests run on samples using no added oxidizing agent. However, addition of increasing amounts of potassium persulfate to samples led to results that appear to be zero order. Concentrated potassium persulfate was added at the rate of 10 ml every 15 minutes of sample contact time in the reactor, resulting in an addition rate of 1000 ppm per 15 minutes.

The results in the first three cases (benzoic acid, phenol, and cyclohexanol) indicate that complete removal of TOC can be achieved quickly using UV photolysis with added potassium persulfate oxidant. The last two cases (methylene chloride and 1,1,2,2,-tetrachbroethane) show similar rapid removal. These tests were secured prior to complete removal of TOC, but there is nothing to indicate that this would not occur.

The results of this study indicate that complete destruction of organic solvent can be achieved easily with UV photolysis using potassium persulfate as an oxidizing agent. When compared to other available technologies used in pretreatment of small volumes of industrial wastewaters, such as adsorption, combustion, or air stripping, UV photolysis can completely remove a solvent to harmless inorganic byproducts without the cost, supervision, or disposal problems associated with them. Further, it would not shift the problem from a water pollution to an air pollution or disposal one.

SUMMARY

The results presented in this paper describe a non-traditional approach to pollution prevention based on research, technology transfer, and education. This cooperative federal, state and trade association waste minimization research approach emphasizes a nonregulatory means of encouraging small and medium-sized generators to use innovative technologies and management practices that can both reduce pollution and provide economic benefits. The EPA's Science Advisory Board also supports this approach to waste minimization, especially for medium-sized generators. The research conducted in Minnesota and the technology transfer set up through GRCDA and the states helps to meet the need for responsible pollution prevention research and application. Each of the research projects supports alternative technologies to encourage waste minimization and improved waste management.

As part of EPA's objective to continue to develop alternative technologies through its newly named Risk Reduction Engineering Research Laboratory, it has developed the Waste Reduction Innovative Technology Evaluation (WRITE) Program. The overall goal of the WRITE program is to promote the national waste minimization policy by cooperative involvement of government with private industry in order to continue to encourage development and demonstration of effective technologies for pollution prevention, or waste minimization.

No longer can we as a nation focus on end-of-pipe pollution control. It is becoming evident to policy makers and industry alike that pollution prevention offers a much greater potential for controlling pollution and preventing degradation of our environment. Instead of striving for better ways to control, treat, or dispose of wastes, our society must think about ways to improve efficiency, and reduce or eliminate waste generation.

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